CO-116

GIS IN GEOSCIENCE TRAINING: AN EXPERIENCE IN PEDAGOGICAL ENGINEERING

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ABSTRACT

With the development of geographic information technologies (geomatics), applied geosciences professions require more and more computing capabilities. Important skills to acquire include those related to the acquisition of reference data, the spatial nature of environmental data and spatial analysis, the methodologies, and the tools of geographic information systems (GIS). In France, a gap currently exists between the level of geosciences training offered at the university level and the skills needed by professionals. To address this issue, we present herein a course in which students solve an environmental problem using the software platform ArcGIS as a decision tool. The first phase in developing this course consisted of an overview of the evolution of professional practices in applied geosciences and an analysis of training opportunities currently available in France with regards to GIS. This phase is followed by the design and implementation of an educational framework. A pilot study was also performed with students, and the preliminary results are presented herein.

1. INTRODUCTION

In his report “Employment perspectives in the Geosciences up to 2020” for BRGM 2008, Jacques Varet emphasized the evolution of the field of geosciences and the skills demanded of young graduates. He asserted that “in recent years, the specializations chosen by geosciences graduates are associated, for the most part, with the environment and development sectors,” disciplines that demand, to an ever greater extent, the use of geographic information systems (GIS). However, when we asked geomatic professionals, educators, and students if young geosciences graduates arriving on the job market today were sufficiently competent in GIS to fill jobs involving GIS (a subject increasingly present in the field of geosciences), they unanimously replied “no.”

The university curriculum that prepares students to enter the field of geosciences appears, therefore, to have shortcomings in teaching or training GIS skills. Our goal is to reduce these shortcomings by treating the following two questions:

(i) What pedagogical system would equip students with the requisite skills to use GIS and still contribute to improving their general geosciences education?

(ii) How could such a system be generalized to other territorial issues and to other educational sectors?

To address these questions, the pedagogical project “@atelierSIG_Geosciences” (GIS Geosciences Workshop), undertaken at the Université Joseph Fourrier (UJF) in Grenoble in partnership with the company Esri France, the Laboratoire Informatique de Grenoble (Grenoble Computer Science Laboratory), the Observatoire des Sciences de l’Univers de Grenoble (Grenoble Observatory for Sciences of the Universe), and the collaboration Systèmes d’Information Géographique pour l’Environnement (Geographic Information Systems for the Environment; SIGENV), has developed a semiautonomous online learning system that has two objectives: (1) encourage the acquisition of GIS skills by offering a flexible module-based curriculum and (2) evaluate the pedagogical gains for students that result from the integration of GIS courses into their curriculum. More precisely, this system should familiarize students with the use of a GIS, help them to conceive and model processes for data analysis, encourage them to participate in the construction of their portfolio of skills, and stimulate their involvement and autonomy.

Before discussing the conceptual and pragmatic aspects of the proposed pedagogical system, we must briefly analyze the needs from the point of view of the evolution of career paths and practices in applied geosciences, as well as from the point of view of the university educational offerings.

2. ASSESSING THE NEEDS

2.1 Evolution of practices: applications of geographic information systems (overview Géologues, no. 164)

The advance of GIS applications in applied geosciences is undeniable from either the viewpoint of career paths (e.g., geological mapping, hydrogeology, applied geophysics, industrial minerals …) or from the viewpoint of the skills required as a professional in the domain. Several tasks and methods depend completely on GISs: designing and implementing a geo-referenced database (e.g., Topo and MNT databases from the IGN), the precision of position data (GPS), acquisition of geo-referenced data, threedimensional (3D) visualization, the normalization of geographic data, and the interactive use and distribution of maps over the internet. However, in earth sciences, a GIS is not an end in itself. The final use consists, rather, of the goal and vision of the geologist, and these aspects are what determine the specifications and structure of a GIS.

A geologist that masters a GIS is able to

1. manage the data flow
2. perform spatial analyses (multicriteria and geostatistical spatial queries)
3. produce new data (slope maps, interpolation and kriging, etc.)
4. produce reports (study and summary maps)

However, to provide pertinent and valuable information, the geologist must add to his mastery of these skills his ability to critically analyze the data.

2.2 Educational offer in applied geosciences in France

In France, as of 2004, 97 master degrees are based on earth and planetary sciences. Today, one finds geo-scientific curricula in 35 French universities, and most of these curricula are geared for environmental studies (J. Varet, 2008). It seems self-evident that the acquisition of GIS skills, which are today indispensable for a career in the geosciences, must be assured by the university degree programs. However, upon examining the content of masters programs offered in France in the 35 universities and upper-level schools, we find that GIS courses are not systematically present in all the degree programs. If they are offered, they often appear at the end of the curriculum (3rd or 4th semester) and are given approximately 15 hours. As such, they serve more as an introduction; all the more so in light of the fact that they are often students' first opportunity to familiarize themselves with GIS.

One ambiguity may arise with regards to the distribution of GIS in French higher education because of the nonetheless large number of GIS courses offered by degree programs in the social sciences and possibly in computer science. However, these programs produce specialists in the use and development of these systems. Programs in the earth sciences use GIS as a tool to help resolve problems encountered in the field and which are dealt with as they arise in the curriculum. This approach explains the low number of GIS courses offered in the geosciences degree programs.

The brief survey conducted within the frame of geosciences GIS courses at the University of Grenoble confirm that the pedagogical methods are, on the one hand, one-off as opposed to progressive and, one the other hand, characterized by a very technical approach (introduction to the computing environment and to the organization of the tools, manipulation of the primary functions, creation and publication of maps). The student labs observed were, for the most part, designed by the educator who did not seem to draw much material from existing internet resources (e.g., ESRI Education community, Institut National de la Recherche Pédagogique, UCGIS Model Curricula). In fact, we must emphasize that university educators manage their programs in a fairly autonomous manner; they design their courses according to the topics that they believe are priorities and which often reflect their academic "origins." This is also linked to the availability of the data, which are not only specific to the given problem but also subject to copyright restrictions of varying degrees of severity. To create a student lab, an educator must rely on the data at hand at her institution, and this availability (or lack thereof) may influence her choices for which student lab to assign to her students.

We find that, if the educator is a computer scientist or geomatician, her teaching is very technical and lacks context: the emphasis is on the software functions. Conversely, if the lecturer is more of a thematic expert, the emphasis will be on usefulness of GIS for solving problems and the functional aspect will be neglected. This situation can cause significant problems in terms of interoperability of the data, their treatment, and the usefulness of the tool.

The small number of hours devoted to teaching GIS does not facilitate the development of the resources. Where GIS student labs oriented toward projects could intervene in a multidisciplinary or transverse manner, the short time allotted to geomatic courses penalizes the implementation of such initiatives.

To overcome these difficulties, we designed a pedagogical model to teach GIS that, in terms of methods and pedagogical resources, targets the acquisition of the job skills needed to direct a territorial diagnosis. The pedagogical model remains close to real situations by offering problems that are typically encountered by professionals in the field, and it is formalized at a level that allows it to be used for the current subject and to be reformulated for different subjects.

3. THE LEARNING SYSTEM

The conception of the pedagogical system—from the definition of the scenario to the pedagogical methods, from taking into account the autonomy to the organization of the work schedule, or even from the implementation of the computing environment to the data management—all rests, on the one hand, on notions of patterns issued from research into pedagogical engineering and into Computing Environments for Human Learning (Envronments Informatise pour l'Apprentissage Humain, or EIAH, Villiot-Leclerq, 2007) and, on the other hand, on the pedagogical approach. of problem-based learning.

To build our pedagogical system, we retained, from among the different conceptions of pedagogy, the approach based on patterns and the modeling of knowledge or skills. G. Paquette (2002) underlines the importance of identifying the knowledge, making it explicit, and representing and modeling it before conceiving the pedagogy. "In pedagogical engineering, the first questions that arise are: What knowledge to acquire? What knowledge to teach? What skills to attain? […] We then associate to this knowledge a capability to define the principle skill that will orient the construction of the scenario." (Paquette, 2002, p. 152)

The type of learning process which was chosen belongs to the field of socio-constructivist theories with an "active" approach (Lebrun, 2002) for problem solving. Lebrun and Berthelot (1994) define the latter as "the systematic study of problematic situations, hypothetical or real, with the goal of evaluating the nature of the problem, of analyzing the data, of choosing the applicable principles, and, finally, of recommending a solution." We can equally find some footholds in the definition of the "problematic situation" of A. Le Roux (2004), who "confronts the student with a problem that requires him to take responsibility for the social or scientific stakes." In his thesis, S. Génevois (2007) asserts that "this approach is perfectly applicable to performing case studies with a GIS, which is not just a database," but "an ad hoc scientific and technical construction implemented to answer one question or to solve one problem." (Joliveau in Génevois, 2007)

Based on the concepts discussed above, our system will contain the following elements:

- scenario and didactic structure;
- pedagogical resources,
- tutoring support

3.1 Scenario and didactic structure

The scenario is constructed with the following objectives:

1. develop the technical skills to master GIS skills;
2. reinforce the methodological skills for spatial analysis (acquisition of a global vision of the real-world problem that accounts not only for the environmental constraints such as geological, geomorphologic, climactic, etc., but also for the geographic context such as urbanism, construction layout, etc., of the survey zone);
3. master the management of a project by using a GIS in a professional environment (set up a feasibility study of a soil by using the new technologies).

These objectives have been identified based on the survey cited above, which demonstrated flagrant deficiencies in methodological skills and techniques and in the management of expertise.

This scenario is conceived to place the targeted skills in context, which is justified by the fact that the students are preparing themselves for a future career in which they will have to target the appropriate GIS functions to resolve problems from the field. In other words, we have searched for a system that exposes students to authentic experiences (Simon, 1962) by placing them in situations modeled on the professional world. The scenario consists of giving a mission and a role to the students, as if they were members of an engineering consulting firm. They are required to carry out a study to define and determine the feasibility of "the most appropriate sites in southern Isère to install a vineyard."

To fulfill this requirement, the students follow a six-phase scripted to reproduce the global investigative processes applied in the field of the geosciences (e.g., the field of geophysics and/or geotechnical). The phases are divided into several activities, and resources and tutoring complete the system.

Table 1 presents the architecture of the course and the skills targeted at each phase.

Structure	Contents	Geological Skills	GIS Skills	Teaching aid	
Introduction	Explaining the context and how the workshop will carry out	Appropriate problem's criteria		Activity : Write a statement of work: specify the processes involved to solve the spatial problem (ws)[1]	Material en resources on « vineyard »
Step 1	Searching and collecting data	Observe and analyze the soil	Manage and visualize data	Activities : 1. Parameters (ws) 2. Nature of data (ws) 3. Data files (ws)	Support folder : 1. Geographic data types and formats
Step 2	The data management		Create a database with spatial reference	Activities: 1. Spatial reference Systems (ws) 2. A file database	Support folders : 2. Spatial reference Systems 3. ARCGIS database
Step 3	Geoprocessing	Transpose geological tasks to computing tasks	Familiarise with the main surface analysis tools	Activities: 1The main functions to know 2. How to choice the functions (ws)	Support folders : 4. Working with raster data set 5. Surface and Spatial Analysis tools
Step 4	Overlay analysis and suitability models	Represent an analysis process	How to combine different layers	Activities: 1. Process and weighting (ws) 2. Create a graphic model	Support folder : 6. Model Builder
Step 5	The survey report	Write out an expert's report	Add a decision-making map in a report	Activities: 1. The final report 2. Take a decision	Support folder : 7. Saving, exporting and loading a map

[1] ws= worksheet

Table 1: Course architecture.

Thus, the scenario that combines an approach modeled on "scientific investigation" and methods and tools for multicriteria spatial analysis consists of :

1) Formalizing contractual specifications
2) Identifying the data needed for the analysis
3) Putting on a geodatabase
4) Making geo processes for raster data set
5) Classing the weighted layers and overlays
6) Using feature class analysis tools
7) Creating a map of suitability
8) Analyzing the results.

3.2 Pedagogical resources

To help the students complete each phase, a collection of worksheets are available that contain preparatory exercises (tables to complete, questionnaires …) to aid the student to accomplish the task required in each phase. These exercises allow the students to build their knowledge in stages. Also available are a collection of documents to facilitate the learning of GIS skills. These consist of documents designed to introduce basic geomatic notions and to guide the students in the use of the software.

3.3 Tutoring support

The tutoring is organized in 5 classroom teaching sessions, each lasting two hours, and an email-based online follow-up that allows students to address the tutor the moment a need arises. The five classroom sessions are devoted to presenting the workshop and the digital work environment (1), presenting the requisite methods and techniques to resolve the given problem (3), and collecting the students' work (1).

4. PARTICIPANTS AND TOOLS

The Geosciences workshop was tested with first-year students from the Observatory for Sciences of the Universe of Grenoble (OSUG) masters program in Professional Earth and Environmental Sciences, who specialize in geology, hydrological risks, and subterranean hydrology, and whose postgraduate career opportunities include essentially small- and medium-sized engineering consulting firms. The students were divided into small groups (2 to 3 people) and were tutored autonomously. The workshop lasted 8 weeks.

Two computing environments were used:

1. The DOKEOS learning platform, which hosts the system and allows the creation, organization, observation, and supervision of the online learning activities.

2. The geographic information system (the Arc GIS software package version 9.31), which is used for data management, calculations of the surface, and to create the final map.

5. METHODS AND FIRST RESULTS

To evaluate the benefits of the system, we set up an investigative protocol that allowed us to identify the students' main shortcomings and their progress. For this, we analyzed their work and conducted individual interviews after they completed the workshop.

The analysis of their work was based on their worksheets and the language they used to express their knowledge. The most interesting results for estimating their technical and theoretical knowledge came from analyzing the contractual specifications, the worksheet concerning the data format, and the questionnaire. The difficulties observed involve several technical aspects:

1. identify the format that corresponds to the data used,
2. distinguish between feature and raster modes,
3. distinguish between the geographical coordinate system and the system for geographical projections and several methodological aspects,
4. set up of a feasibility study and managing a small project, from the theoretical approaches to the pragmatic factors.

The interview allowed us to pinpoint the evolution of the students' perceptions concerning the methodological and technical knowledge needed to successfully perform a feasibility study. For this, the students were interviewed with the same questions before and after the module. These interviews were conducted based on the grid constructed around the following questions: What vision of GIS did they have at this stage in their university career? What general vision did they have of a career in the geosciences? What professional knowledge do they use to perform a feasibility study, and how would they formulate and implement a GIS project?

Table 2 presents a summary of the results that led us to define three priority skills.

	Observed Skills
	1. Structure and Management of territorial diagnosis
Before workshop	In the entrance interviews, all the students were questioned about the way in which they apply their expertise in identifying the most appropriate sites in Isère to develop a vineyard. We found that, most of the time, the sequence of steps was not proper and their implementation of the pragmatic aspects was very vague (notably with regards to the data, their use and treatment, the cartographic report …).
After workshop	In the exit interviews, we asked the students which spatial-analysis method they would adopt to identify the best sites in Isère to develop a ski resort. All were able to formulate a clear and logical procedure that went from multicriteria choices, to research and integration of the data with the appropriate treatments, to the usefulness of creating the cartographic elements.
	2. Set up and application of the technical and analytical possibilities enabled by the tool
Before workshop	In formulating the contractual specifications, the students were unable to specify the treatment or functions needed for the surface calculations or for combining the desired indicators. They do not know how to search for data or how to use them.
After workshop	All the students understood the essential role played by GIS in the interoperability of the data and in rapid data treatment. According to the students, GIS enables terrain studies to be done faster and more precisely.
	3. Appropriation and integration of the tool in professional life
Before workshop	The idea that the students had of a GIS was linked essentially to its visual character with no consideration of its potential for calculating and data analysis. Because of a lack of knowledge, they were unable to position a GIS in the sequence of steps of a territorial diagnosis. They did not see how a GIS can help in the decision-making process.
After workshop	The students feel more at ease with this type of software. They have overcome the "technological barriers" that a GIS can present and are at ease with basic functionalities and algorithms of surface analysis; they are aware of the spread of this tool in the professional domain. They know when to integrate this tool in managing a project.

Table 2. Synthesis of the evolution of the 3 core skills taken from interviews

The analysis of the interviews reveals that their GIS skill level is very low, despite their having an undergraduate degree. It also indicates that the proposed pedagogical system facilitates their acquisition of these skills, and that their interest in GIS is strong and motivated by the perspective of a career whose changes and progress they understand.

6. CONCLUSIONS AND OUTLOOK

We have answered the initial questions by designing a pedagogical system whose benefits have been observed. Because of the integration of a scientific approach into its didactic architecture, this system can be generalized and serve as a model for other pedagogical systems that integrate GIS into the treatment of environmental questions. To use the system, an educator is required to think of a new case study, furnish the data, and prepare several supporting materials. Toward this goal, we are testing the system's adaptability to other subjects and in other universities.

We consider this work as a preliminary prospecting phase that allows us, within a research project, to give two objectives: the design of a new pedagogical system based on establishing learning situations that mirror, to the extent possible, typical professional situations for applied geosciences, and the development of a rigorous experimental protocol to measure the students' cognitive (process) development.

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